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Using Al foam to reduce the transfer of impact stress between ceramic plates.

Final Technical Report No.2

by

Ing. Milos Bortel

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ZTS-MATEC, a.s.
Areal ZTS No.924
018 41 Dubnica nad Vahom
Slovakia

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14. ABSTRACT
The objective of this project is verifying the use of Al foam as a damper of pressure wave between adjacent ceramic plates of the metallic ceramic armour. The use of Al foam as a bonding agent of ceramic plates and the metal base was also verified.

15. SUBJECT TERMS

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1. Abstract:

The objective of this project is verifying the use of Al foam as a damper of pressure wave between adjacent ceramic plates of the metallic – ceramic armour. The use of Al foam as a bonding agent of ceramic plates and the metal base was also verified.

2. Design and production of samples:

Two fields of dependence have been examined in this project:
1. The influence of the distance between particular ceramic plates on the transfer of stress and on filling with foam;
2. The influence of the distance between ceramic plates and the base on the transfer of stress.

Within the framework of the project No.N62558-03-M-0815 the samples of foam – ceramic armour of geometry according to Fig. No. 1 have been produced.

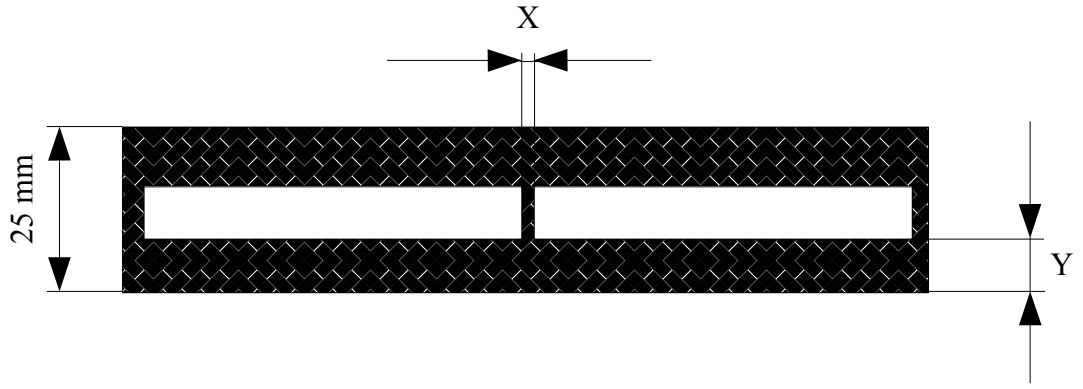


Fig. No. 1

Ceramic plates of dimensions 50 x 50 mm have been produced from Al_2O_3, with the following parameters: specific weight = 3,75 g/cm^3, hardness = 1250 HV30, strength in bending = 300 MPa.

We succeeded in producing 13 pcs of panels of dimensions of 300 x 300 mm, of thickness 25 mm, which can be used for firing tests. After producing, strips of 20 to 30 mm in width have been cut out of the panels in order to find out actual produced spacing between the ceramic plates.

It was proved that using this technology it is problematic to keep the required spacing between the plates themselves as well as between the plates and base. The table presents the required and actual measured spacing.

Panel No.	*required spacing [mm]*		*actual spacing [mm]*	
	X	Y	X	Y
1	4	8	5	10
2	4	6	5	10
3	1	6	2	10
4	3	8	3	8
5	3	6	3	12
6	0	8	0	6
7	0	6	0	10
8	2	2	2	1
9	3	2	2	1
10	2	6	2	8
11	1	8	1	10
12	2	8	2	12
13	2	6	2	6

In spite of we did not succeed in producing spacing in accordance with our requirements we have panels with the width range of spacing, so the original intent of the project is unchanged.

After failed attempts to bond the foam – ceramic block and the base within one step the decision was made to bond the foam blocks and base sheets – material 11 523 according to STN (1.0570, SAE 1024) (STN = Slovak Technical Standard), thickness 2 x 6 mm - by means of an adhesive. This method was used to produce panels with the geometry according to Fig. 2.

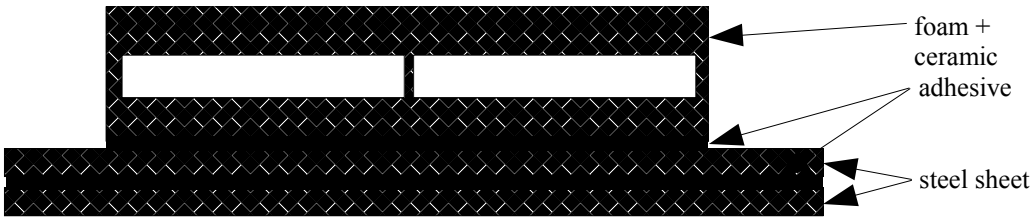


Fig. No. 2

3. Shooting tests:

Shooting tests were made in the third part of this project. Samples were fixed in the holder perpendicularly to the direction of shooting. There were 5 shots shot at each sample and shots were directed at same places at all samples, 7,62 x 51 AP P80 (Hinterberger - Austria), distance 30m,

velocity from 843.8 to 869.3 m/s, what meets requirements STANAG 4569, Level II. Once the tests were made the front and rear sides of all samples were documented.

4. Inspection of damage of ceramic plates:

After execution of firing tests Al foam was removed from the front sides that it was possible to inspect damage of ceramic plates. Removing of Al foam from the sample 9 failed because the foam had been separated from the base in the course of preparation stage, what caused partial degradation of the sample.

5. Assessment of damage of plates:

The results of damage of ceramic plates are shown in the table. The quantity of plates does not take into account the plates, which were cut to find out spreading after foaming.

Sample	***Damage of adjacent plates***	***Damage of plates / gap***	***Quantity of plates***	
			With no damage	***Damaged***
1	-	1	14	6
2	-	1	15	5
3	+	-	4	16
4	-	1	14	6
5	-	1	14	6
6	+	-	0	20
7	+	-	2	18
8	+ -	+ -	7	14
9	-	-	-	-
10	+ -	+ -	7	14
11	+	-	10	10
12	-	+	9	11
13	+ -	+ -	11	9

Explanatory notes:

1. Damage of adjacent plates:

- „+“ = Yes,

- „-“ = No

2. Damage of plates / gap:

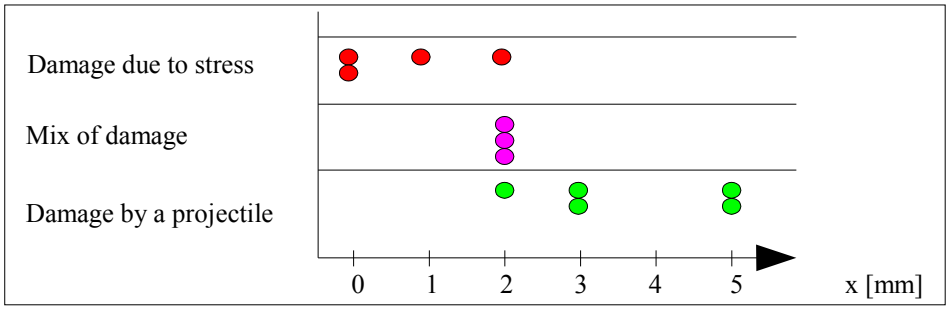
- „1“ = Projectile hit the area near the gap and 1 adjacent plate was damaged by a projectile (not by the transfer of stress);
- „+ -“ = It is not possible to determine whether damage was caused by a projectile or by the transfer of stress;
- „-“ = Damage was caused by the transfer of stress.

It is possible to divide damage of ceramic plates into 3 types:

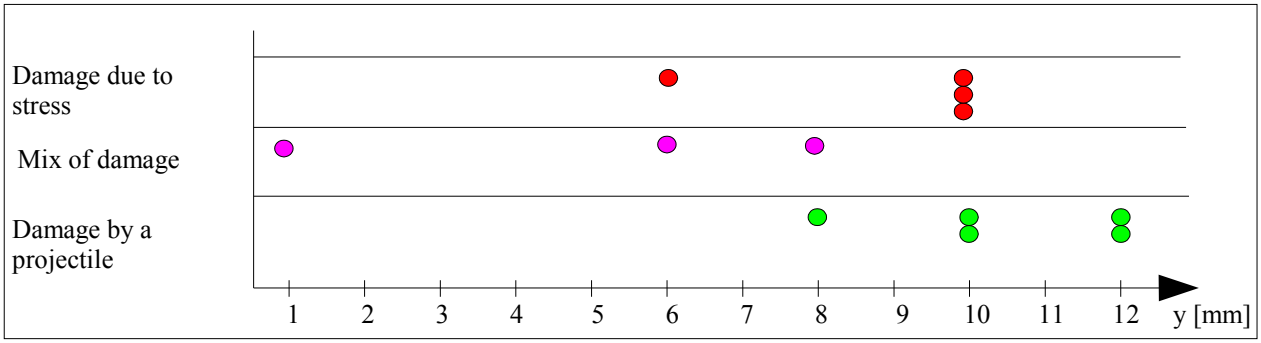
- By direct hit;
- By partial hit (penetration of a projectile through the gap between plates);
- By stress from an adjacent plate.

From the point of view of stress it is possible to assess the samples of 1, 2, 4, 5 and 12 as acceptable (in principle the transfer of stress between adjacent plates did not occur). Minimally partial destruction of adjacent plates occurred on the samples of 3, 6, 7, 11 and 13 (starting from chipping up to total destruction). Damage of the rest of samples occurred only sometimes.

The following charts present dependence of types of damage and distances between adjacent plates (x) and between plates and the base (y).



Type of damage in dependence on the distance between adjacent plates „x“



Type of damage in dependence on the distance between plates and the base „y“

6. Summary of the obtained results:

On the base of results of this work it is possible to express the following conclusions:

1. Motion of embedded structures occurs in the course of foaming. These structures have to be fixed against motion and if fixed washers are used this connection can create a fixed join of adjacent plates (base) and thus eliminating the function of foam. This problem would be solved in an independent task if the project were continued.

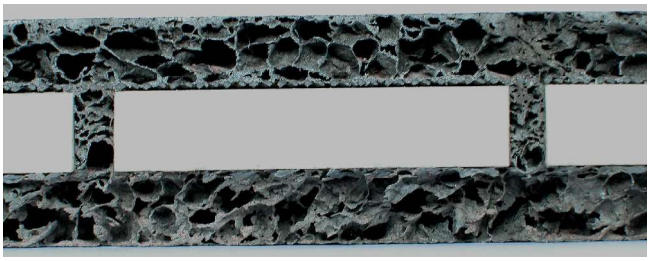
2. Connection of ceramic plates and the base within one step by means of foaming and using conventional technologies shows to be unreal. In our opinion it is not necessary to continue in solving this problem, because degradation of mechanical properties of almost all metal materials used for ballistic purposes occurs at the temperature, which is needed for foaming of Al foam (> 700°C). It is possible to continue with solving this problem when foams treated at temperatures below 200°C will be used.

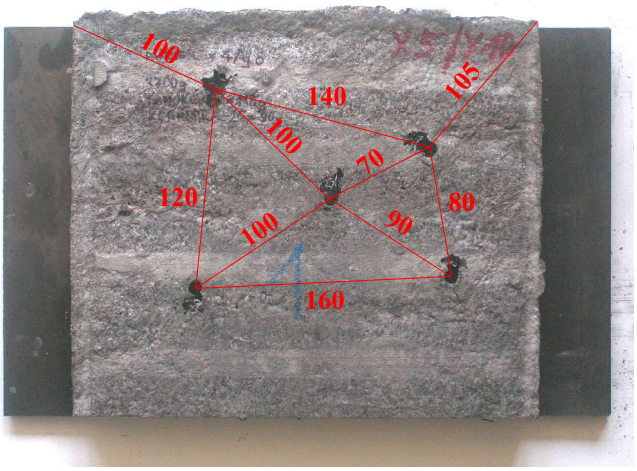
3. For used materials and firing conditions the limiting distance between adjacent plates seems to be the dimension of 2 mm. This is the distance, at which all three types of damage of plates occurred. At a shorter distance (1 mm) there is no opportunity for foam to show its damping effect and at the gap of 3 mm and higher the transfer of stress between adjacent plates is eliminated. Naturally, this conclusion would be verified using higher quantity of samples with focusing on the distances of 2 to 3 mm, if the project were continued.

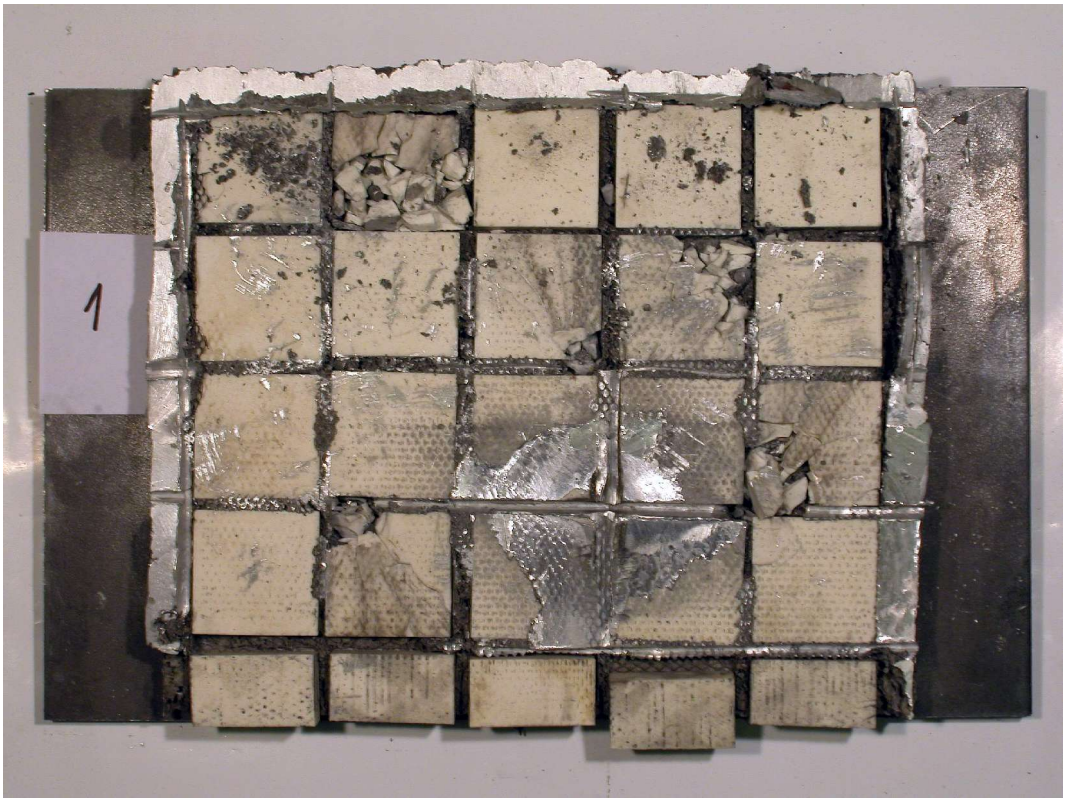
4. At simple gaps of the width starting from 2 mm, when they were directly hit, total penetration of a studied sample occurred. Therefore it would be useful to deal also with solving of elimination of this problem, if the project were continued.

5. The influence of the distance between ceramic plates and the metal base on the transfer of stress between adjacent plates was not unequivocally validated nor refuted by these practical experiments.

Plate No.1







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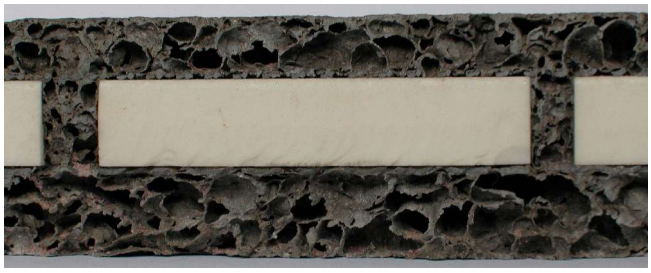

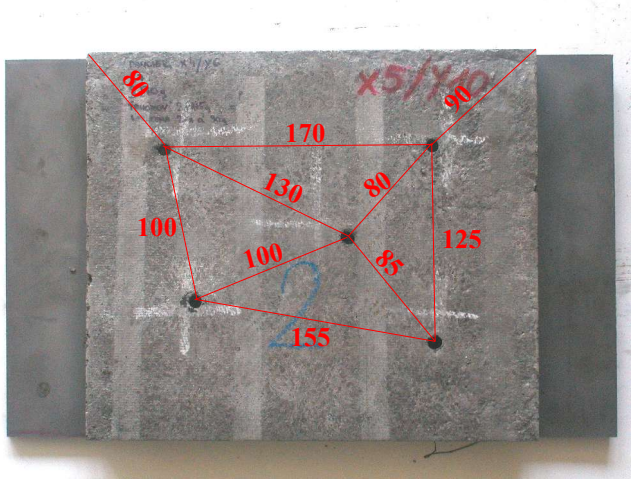

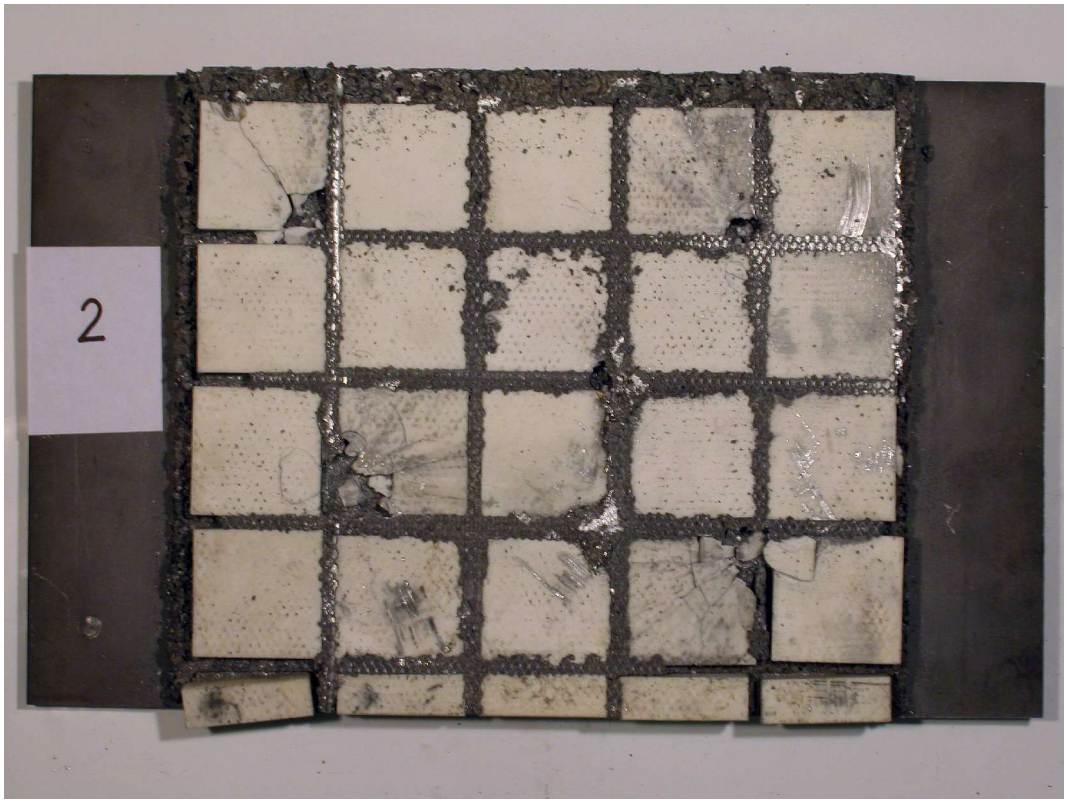

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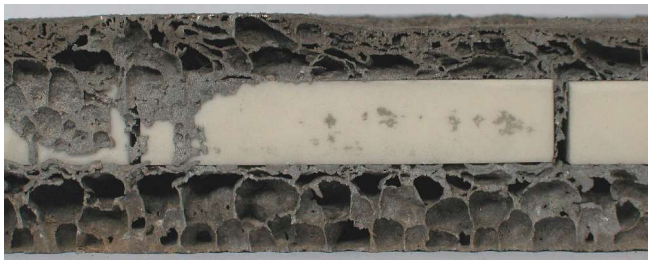

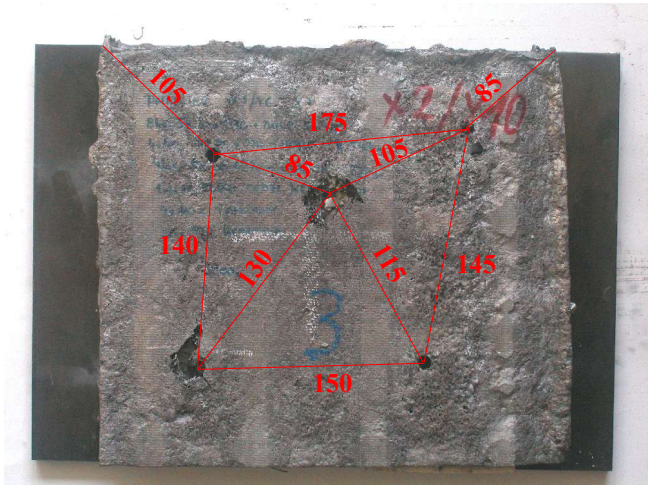

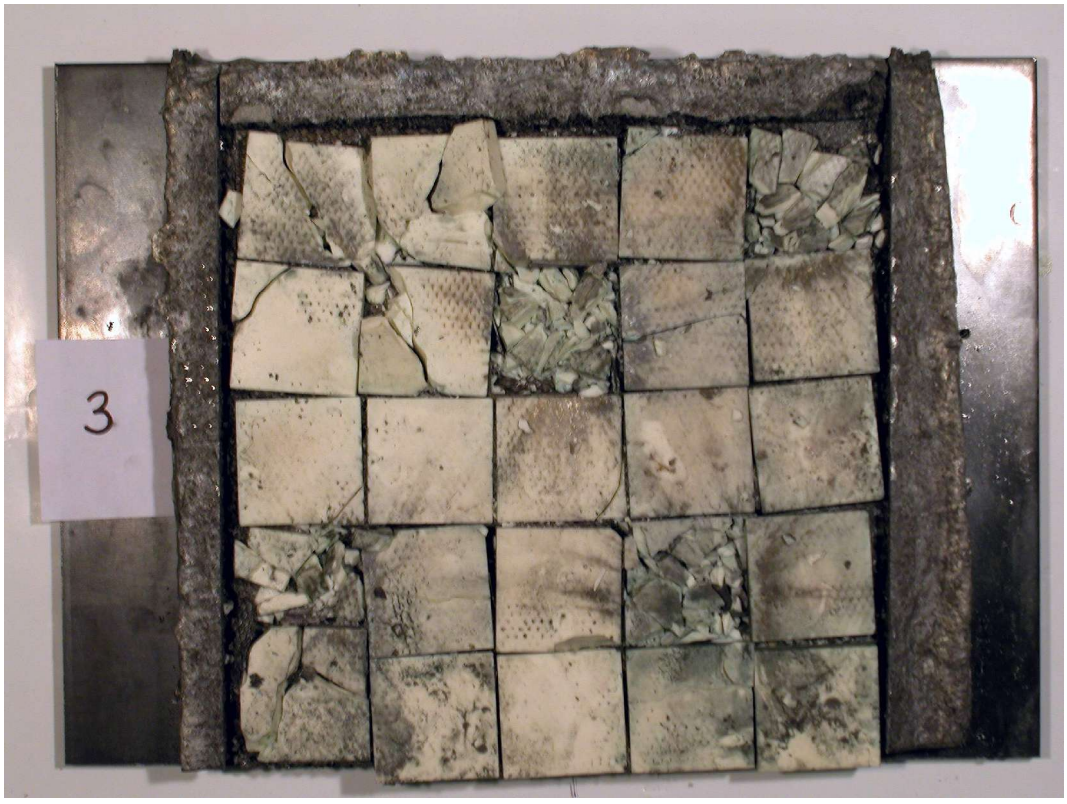

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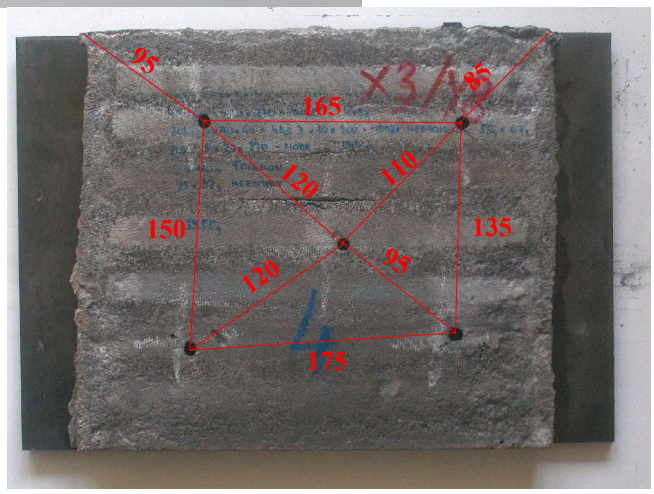

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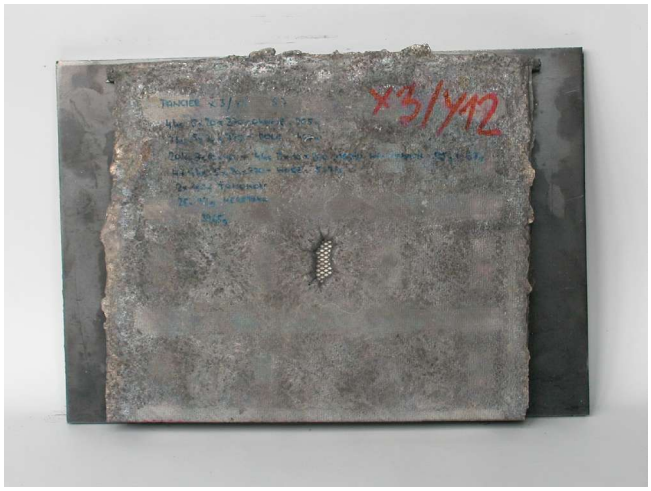

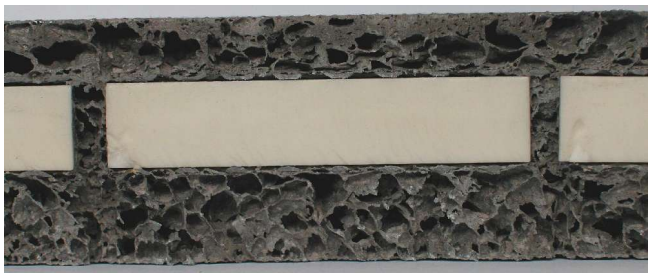

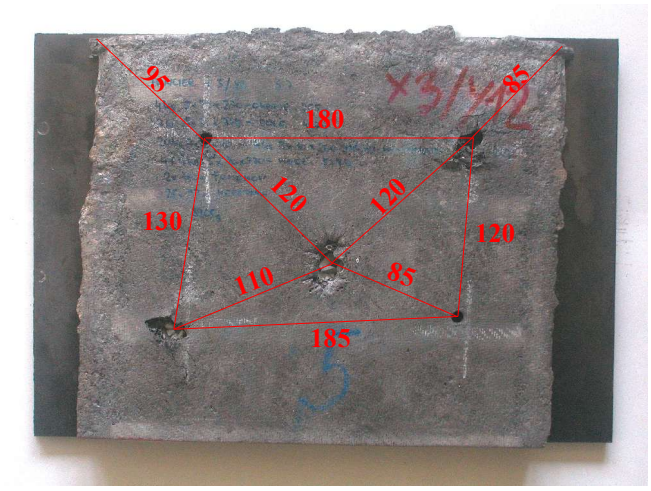

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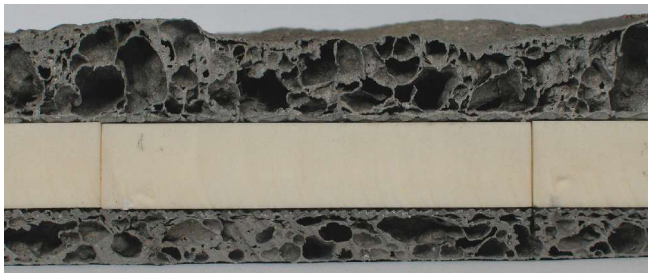

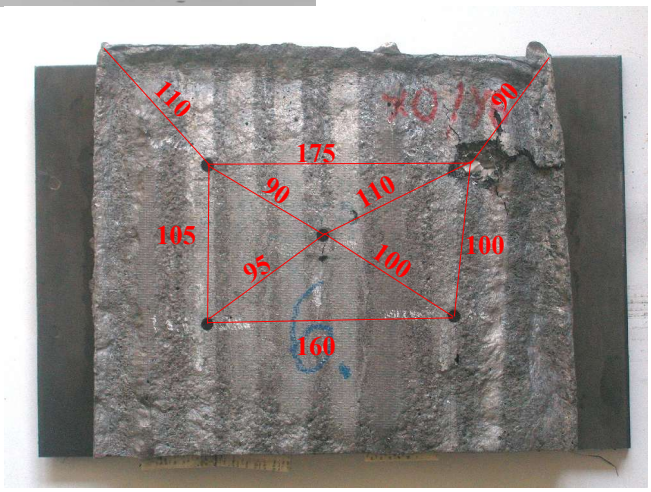

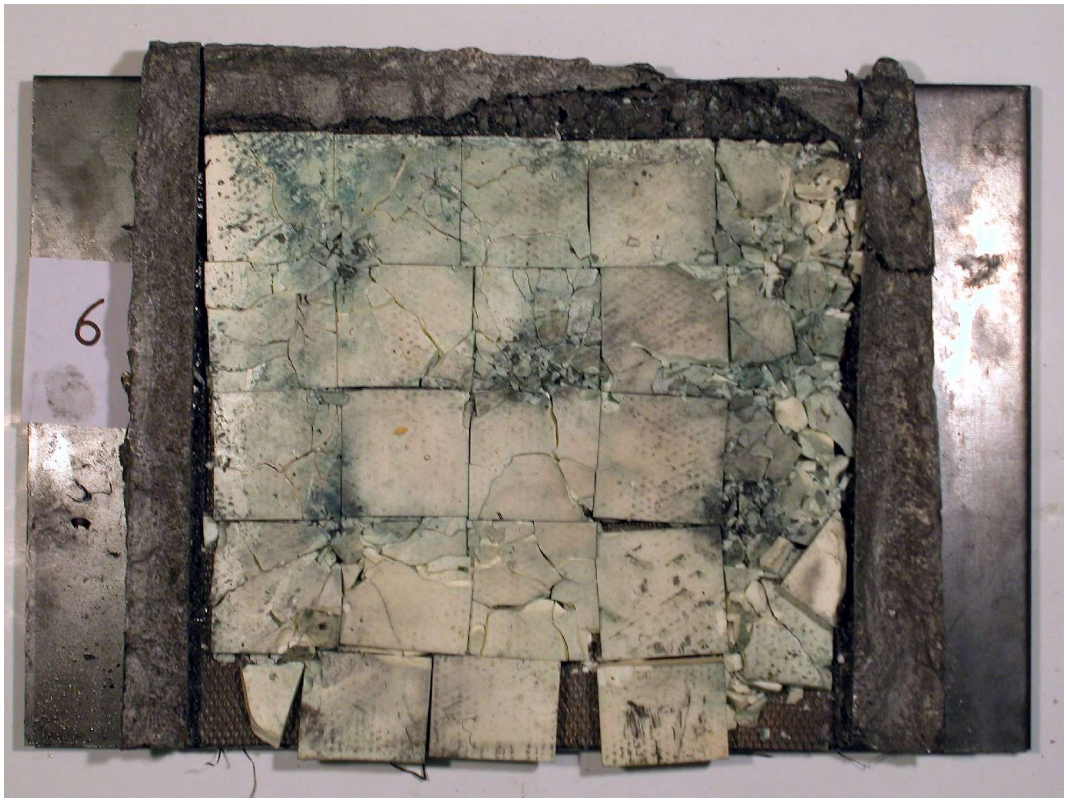

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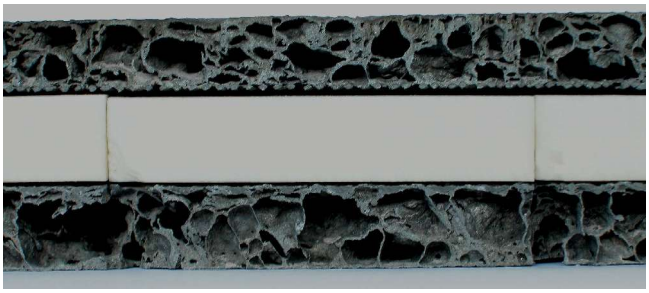

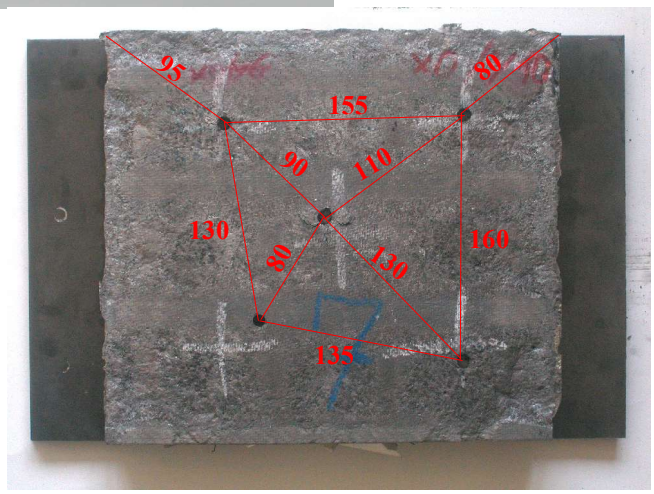

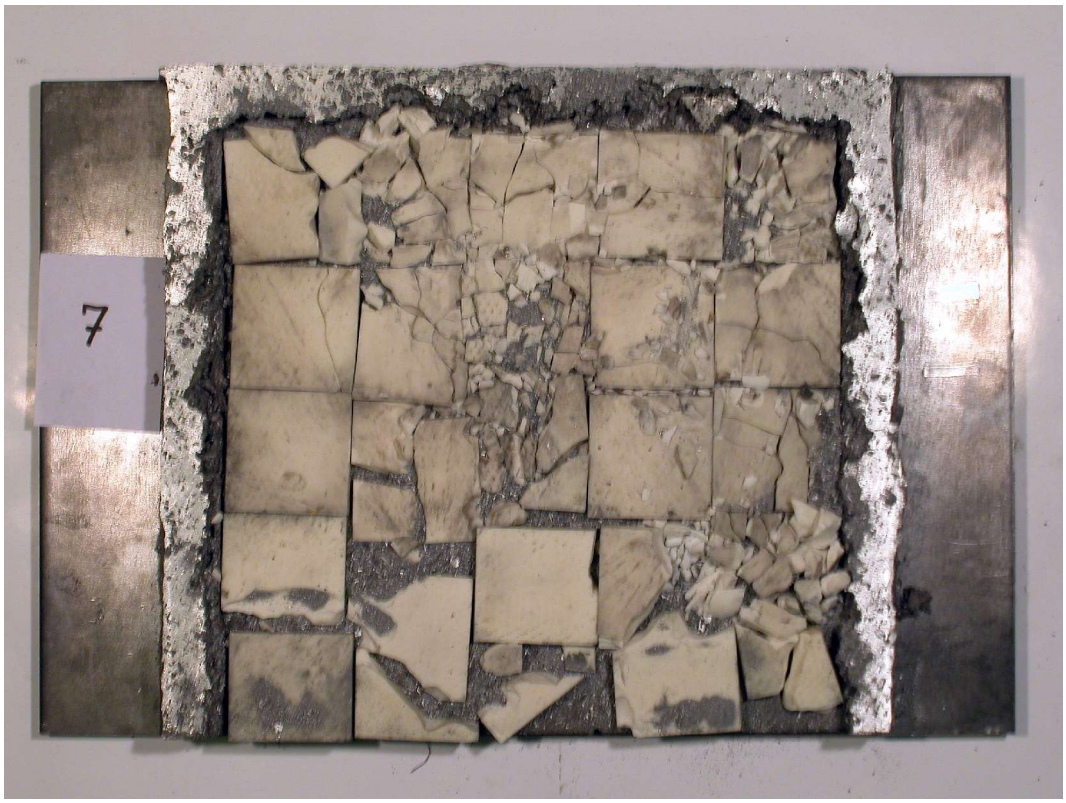

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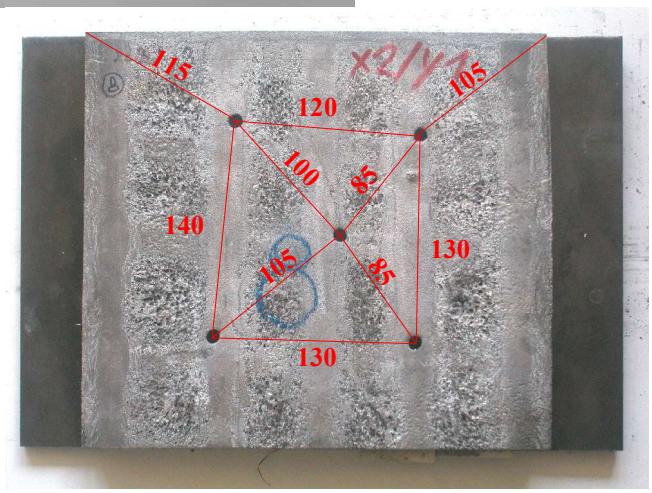

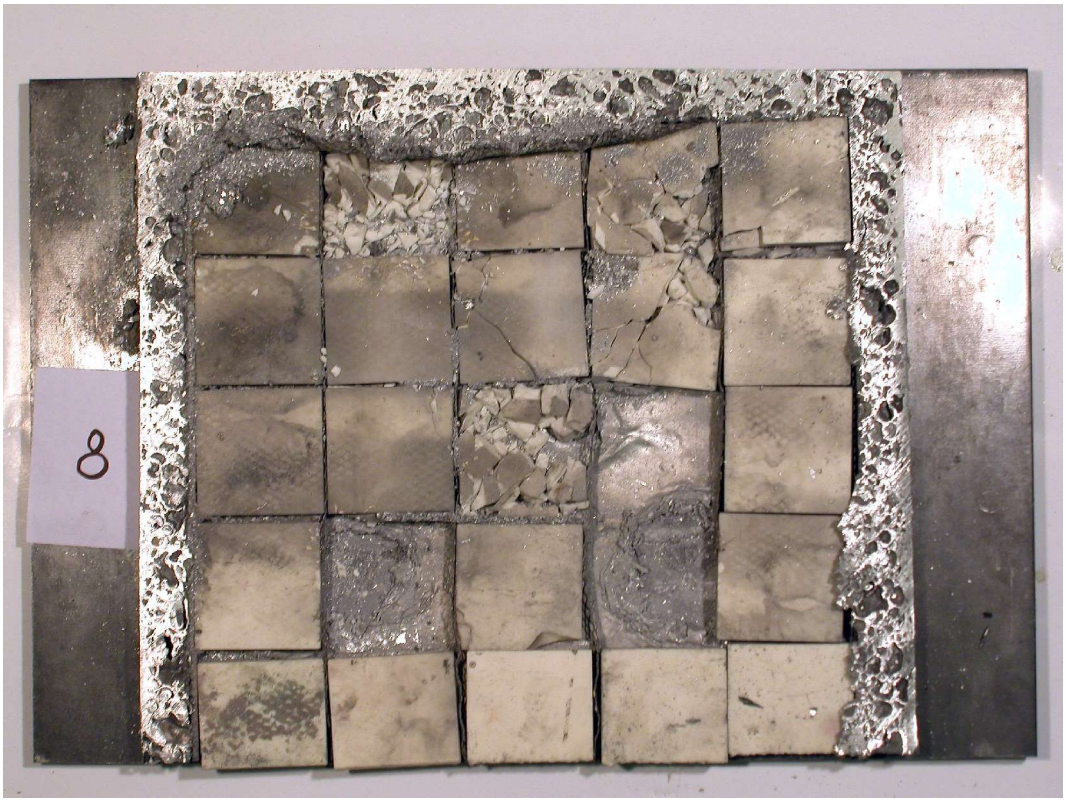

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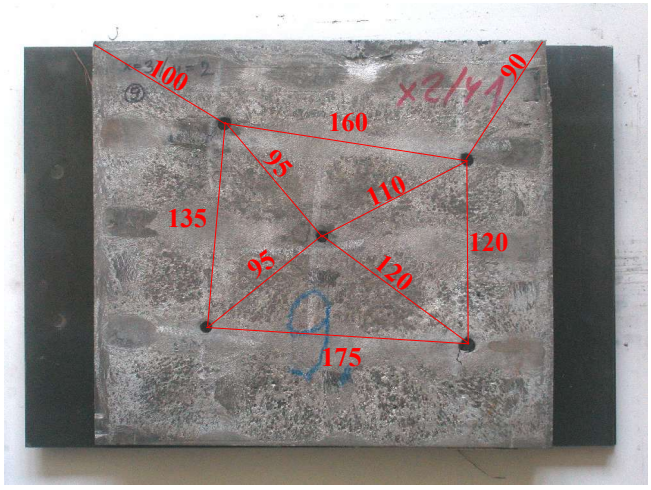

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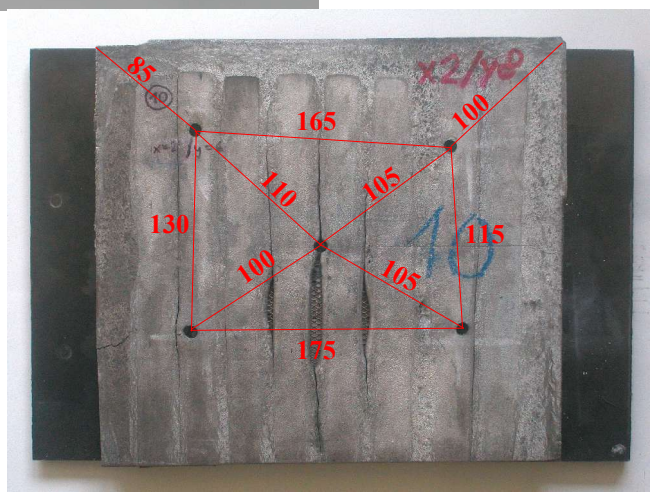

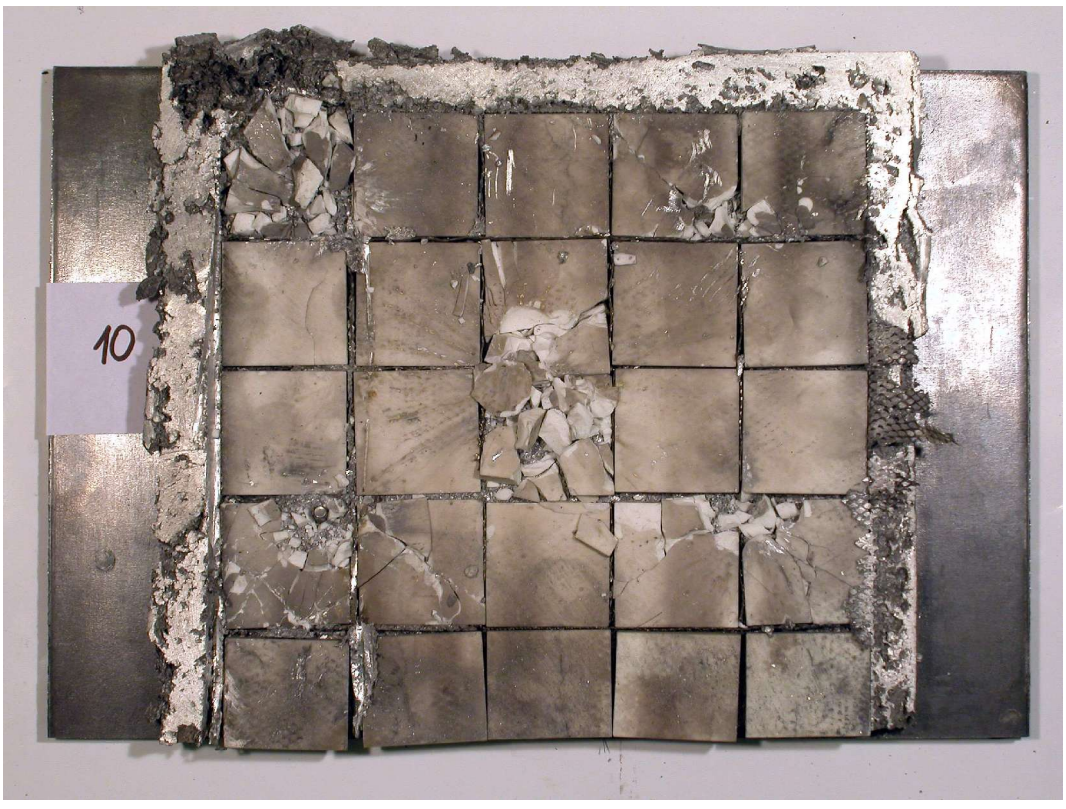

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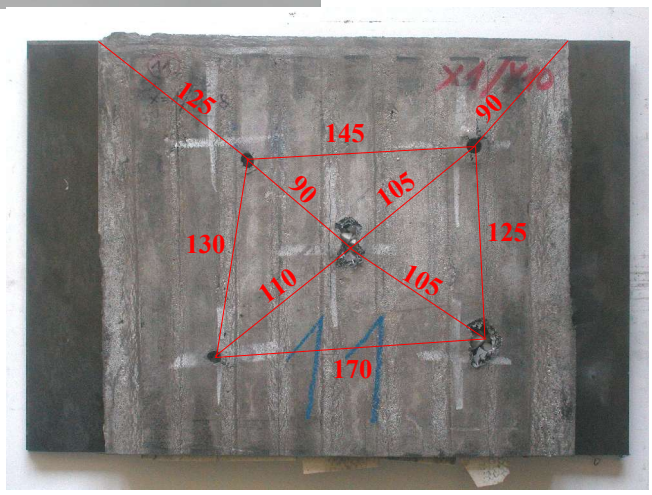

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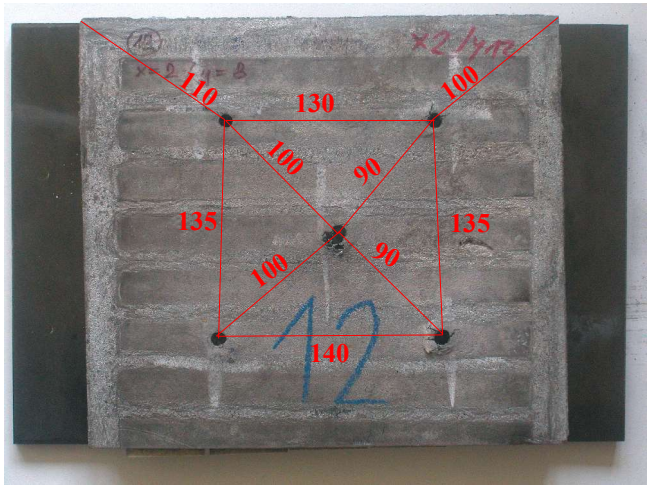

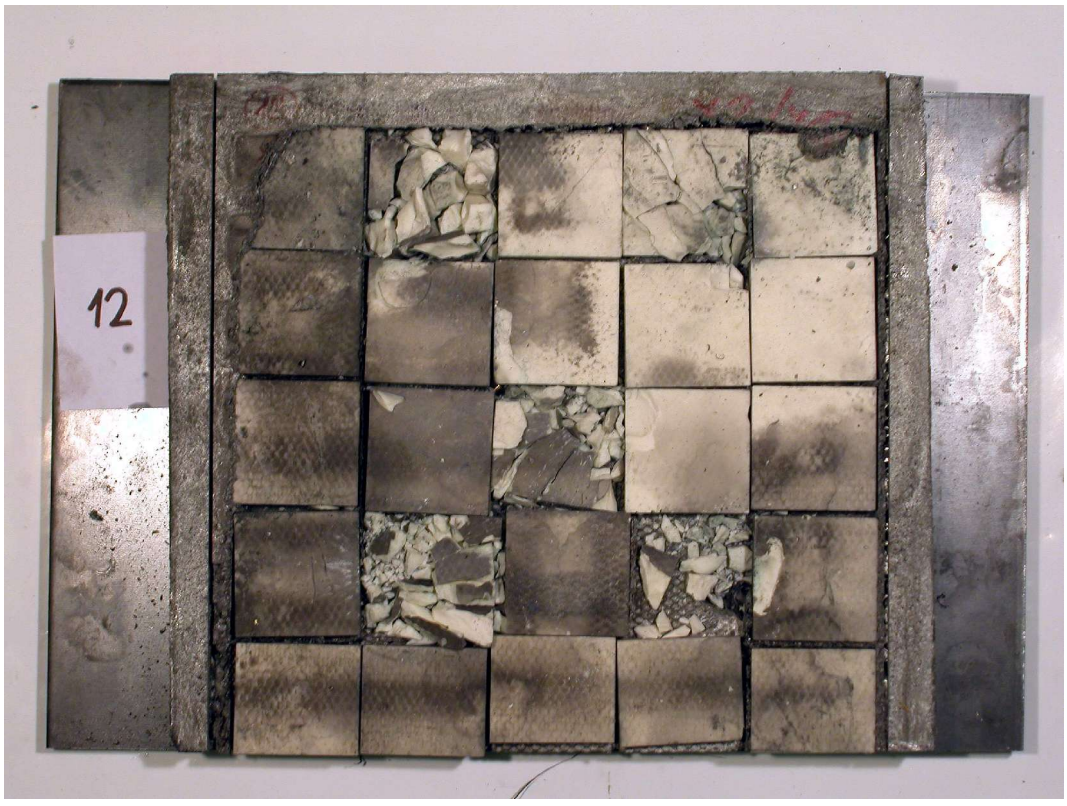

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